Description

C-2469

System for Providing Assured Power to a Critical Load

Technical Field

This invention relates generally to power systems, and more particularly to power systems for providing an assured, or uninterruptible, supply of electrical power to one or more critical loads. More particularly still, the invention relates to such power systems employing fuel cells as a source of electrical power.

Background Art

By far, the most common source of electrical power for a great variety of loads is via the extensive power grid provided by the various electric utilities. The electrical power available on the utility grid is generally fairly reliable as to continuity and adherence to established standards of voltage, frequency, phase, etc. However, from time to time discontinuities and/or departure from those standards do occur. If they are brief or modest, most loads are relatively insensitive to those events. On the other hand, there are a growing number of loads which are relatively intolerant of even brief aberrations in the power supplied by the utility grid, with the principal example being computers and various types of electronic data processing devices. Even brief interruptions in the standardized supply of electric power by the utility grid may cause the computer to malfunction, with sometimes costly, and always bothersome, consequences.

In defining this concern, the Computer Business Equipment Manufacturers Association (formerly CBEMA, and now ITI) has developed a set of Power Acceptability Curves which establish the standards, or at least provide guidance, for determining the power norms which will

assure continued operation of those types of loads. In that regard, a standard has been adopted indicating that a computer can tolerate a one half cycle or 8.3 ms power interruption. The power available on the utility grids is not presently capable of meeting this standard on a substantially continuous basis. Accordingly, it has been and is, necessary to provide supplemental power sources if it is important to assure that critical loads have a substantially continuous or uninterrupted supply of electrical power. For purposes of this application, a supply of power with interruptions or transfers of no greater than 8.3 ms duration, may be referred to as being "seamless", "substantially continuous", or "substantially uninterrupted".

Referring to Fig. **1**, there is illustrated one existing form of uninterruptible power supply (UPS), a so-called "on-line" or "double conversion" type, used to supply a critical load in those instances when the utility grid supply is interrupted or is outside of specified limits. The utility grid power supply normally appears on conductor **110**, and is passed via normally-closed contacts of a 3-pole transfer switch **112** to a rectifier **120**, which supplies the critical loads **114** via an inverter **122**. However, to provide continued power in and during those intervals when the utility grid power is not within the specified limits, a backup battery **116** is provided to supply immediate power of limited duration, and an emergency electrical generator **118** is then connected to the other contact of transfer switch **112** to follow-up with a longer term temporary supply. To accommodate the use of battery **116** in a system which relies on AC power for the loads **114**, it is necessary to provide the rectifier **120** to charge battery **116** and the inverter **122** to convert the DC supply from the battery to the necessary AC supply for the loads. A high speed

switch **124** connected between the transfer switch **112** and the loads **114** operates as a bypass switch to provide temporary power if the inverter **122** or rectifier **120** must be serviced. Because the grid and loads are not normally directly connected, but rather the power to the loads is required to pass through a pair of converters with the aid of the UPS battery, this type of UPS is termed an "in-line" or "double conversion" type. This arrangement, though effective, requires a number of costly components that are in use only during the intervals when the utility grid power is unsatisfactory.

Another arrangement of a power system for providing substantially uninterrupted power to critical loads is described in PCT application US99/10833 for "Power System", published on 25 Nov. 1999 as WO 99/60687. Referring to Fig. **2** in the present application, the relevant portions of the invention described in that PCT application are depicted in a very simplified, generalized form, with elements being numbered such that their last 2 digits are the same as their functionally equivalent counterparts in Fig. **1.** The critical loads **214** receive substantially uninterrupted power from a motor-generator **230** within an uninterruptable power system module **231**, which module also contains transfer switches, rectifiers and inverters. Several alternative electrical power sources are provided to maximize the continued powering of the motor-generator **230.** One such power source may be the utility grid **210.** Another source may be the fuel cell generator power plant **218.** A transfer switching arrangement **212** enables one or the other of the utility grid **210** and the fuel cell **218** to normally provide the power to drive the motor-generator **230.** This type of uninterruptible power supply is also of the "on-line" or "double conversion" type inasmuch as the grid is

not directly connected to the loads **214**, but acts through the rectifier and inverter converters and the flywheel and/or fuel cells to energize motor-generator **230** which in turn provides uninterrupted power. In fact, the fuel cell **218** is configured to operate in a grid connect (G/C) mode with the utility grid **210** for system economy, so in grid connected mode both the grid and the fuel cell supply the "grid" terminals of the transfer switch. In the event of failure of the grid supply **210**, the fuel cell **218** is intended to serve as the continuing power source for the motor-generator **230**. However, in such event, the fuel cell **218** must reconfigure from a "grid connect" (G/C) mode of operation to a "grid independent" (G/I) mode. The power conditioning system (**PCS**) portion of the fuel cell **218** includes associated inverters, switching transistors and breakers (not shown) that effect the conversion of DC power to AC power and that govern the fundamental G/C and G/I modes of fuel cell operation. That mode transition (from G/C to G/I) has typically required the fuel cell **218** and transfer switch **212** to interrupt power generation for up to 5 seconds. Such interruption is not "seamless", and would be of unacceptable duration for critical computer loads **214**. Accordingly, a backup flywheel power source **216** provides immediate power of limited duration(similar to the battery source **116** in Fig. **1**) to the motor-generator **230** at least during such mode conversions. That backup power source **216** is a flywheel **236** driving a bi-directional AC/DC converter **238**. The converter **238** keeps the flywheel spinning during normal operation, and discharges the flywheel **236** during backup operation. The various transfer switches used in the transfer switching arrangement **212** and in the uninterruptable power system module **231** may be electro-mechanical, static, or a

combination thereof, and serve to effect the various power switching functions.

While the Power System of the abovementioned PCT application may provide a substantially uninterrupted source of power to various critical loads and may advantageously employ fuel cells as one of the main sources of the power, it nevertheless requires the use of considerable additional equipment that is complex and costly. For example, the separate motor-generator **230**, and the backup power source **216** which includes the flywheel **236**/converter **238** combination, represent necessary, but expensive, components in order to assure the degree of power continuity sought and required.

Another type of UPS is of the "stand-by" type wherein the grid is directly connected to the loads and a stand-by UPS remains idle, even if connected to the loads, until a switch disconnects the grid from the loads. An example of such a system is disclosed in U. S. patent 6,011,324. The fuel cell and associated inverters are normally connected to the loads, but in an idle standby mode while the grid supplies power directly to the loads. When the grid fails, the fuel cell is rapidly brought to full output power and a solid state switch disconnects the grid. Here, too, a number of costly components are in use only during the intervals when the utility grid power is unsatisfactory. Accordingly, it is a principal object of the present invention to provide a power system for providing a substantially uninterrupted (seamless) supply of electric power to critical loads in a relatively economical manner.

It is a further object to provide such a power system in which one or more fuel cell power plant(s) are utilized to substantially continuously supply power to the loads.

Disclosure of Invention

According to the invention, there is provided a relatively economical and reliable power system for providing substantially uninterrupted electric power to one or more critical loads. A first power source, such as the utility grid, provides sufficient power to supply the critical loads. A second power source comprising at least one, and typically multiple, fuel cell power plants, provides sufficient power to supply at least the critical loads. The fuel cell power plant(s) is/are adapted to be, and is/are, substantially continuously connected to the critical loads and are substantially continuously providing significant power to at least the critical loads. A static switch operates to rapidly and seamlessly connect and disconnect the utility grid to the critical load(s) and to the fuel cell power plant(s), for economical continuous usage of the fuel cell power plant(s). Significant economy is realized by having the substantially continuously operating fuel cell(s) substantially continuously connected to the load, and normally also to the grid. In this way, the fuel cells may continuously deliver their rated power, with the requisite portion going to the critical loads and any excess being delivered to non-critical loads and/or the grid. The static switch may be one or more silicon controlled rectifiers (SCRs), or thyristors. Solid-state switch controls operate to rapidly switch the static switch in 4 ms, or less, to make seamless transfers between the first and second power sources. This switching speed is significantly faster than is obtained with conventional line commutation of thyristors. Further control electronics provide high-speed transitions (less than about 4 ms) in the operating modes of the power conditioning system (PCS) inverters associated with each of the fuel cell power plants. This assures that the fuel cell mode transitions, heretofore normally slow, are at a speed comparable to that of the static switch so as to

provide substantially seamless power transfers of and between the first and second power sources. This allows continuous productive operation of the fuel cell power plants.

The foregoing features and advantages of the present invention will become more apparent in light of the following detailed description of exemplary embodiments thereof as illustrated in the accompanying drawings.

Brief Description of Drawings

Fig. **1** is a simplified schematic block diagram of one type of uninterruptible power supply in accordance with the prior art;

Fig. **2** is a simplified schematic block diagram of an uninterruptible power supply employing fuel cell power plants in accordance with the prior art;

Fig. **3** is simplified schematic block diagram of a power system employing a fuel cell power plant, static switch and site control in accordance with the invention;

Fig. **4** is a schematic block diagram illustrating the static switch in greater detail;

Fig. **5** is a schematic block diagram illustrating the site control in greater detail; and

Fig. **6** is table of the operational mode states of the fuel cell(s) in association with mode-controlling signals.

Best Mode for Carrying out the Invention

Referring to the Drawings, Figs. **1** and **2** depict prior types of uninterrupted power systems as previously described in the Background Art.

Referring to Fig. **3**, there is depicted a simplified schematic block diagram of a power system **8** in accordance with the invention. The power system **8** is connected to utility grid bus **10**, and employs one or more fuel cell

power plants **18** at a site, for supplying 3-phase power substantially continuously to and through load contactors (not shown), to load(s) **14**, usually also at the site. For simplicity, a "one line" diagram, or representation, is used herein to depict the 3-phase supply lines, as well as their included switches, etc. The grid **10**, the fuel cell power plants **18**, and the load(s) **14** are interconnected and controlled through a site management system (SMS), generally represented by the broken line block, or grouping, **11**. The load(s) **14** typically include a number of individual customer loads, at least some of which require a substantially continuous supply of power and are thus deemed "critical loads". The critical loads **14** are typically computers, control devices employing computers, and/or electronic data processing devices. For convenience of explanation and visual distinction, the portions of the schematic carrying the relatively higher voltage/current/power to the load(s) **14** are bolded, in contrast with the lower-voltage, control portions of the system **8**.

The utility grid bus **10** normally provides power at 480 V_{AC} and 60 Hz, as do the fuel cell power plants **18** via lead, or bus, **15**. Switching gear, generally designated **12**, serves to interconnect the fuel cell(s) **18**, the load(s) **14** and the utility grid **10**. In this way, the fuel cells **18** are available and connected for supplying electrical power on a full time basis to the loads **14** and/or to the utility grid **10**, for economical usage of the fuel cells. The switching gear **12** includes a static switch module **17** for selectively connecting and disconnecting the utility grid bus **10** to the loads **14** and to the fuel cells **18**, as will be described. The static switch module **17** includes a 3-pole electrically operated static switch **19** rated at 2000 amperes and capable of performing seamless switching transfer of power in about

¼ cycle (about 4 ms). The switching gear **12** further includes several inter-tie or breaker switches **21, 21A, 23, 23A**, and isolation switch **25**, for further selectively connecting and disconnecting the fuel cells **18**, loads **14**, utility grid bus **10** and static switch module **17**, relative to one another, primarily to isolate the static switch **19** for servicing and continue to provide power to the load(s) **14**. A secondary purpose is to allow large fault currents to flow through breaker **23A** instead of static switch **19** if such a fault in the load **14** should occur.

The fuel cell(s) **18** may be a single power plant, or multiple (i. e., "n") plants, connected to provide power to the loads **14** and/or to the utility grid **10**. In an exemplary embodiment, there are five fuel cell power plants **18**, each being a 200 kw ONSI PC25^{TM}C power plant, for collectively providing up to 1 megawatt of power. In addition to a fuel processor and the fuel cell stack itself, each power plant **18** also includes a power conditioning system (**PCS**) that contains a solid-state inverter which converts DC power to AC power at the desired voltage and frequency. Control of and by the **PCS** further enables conversion of the mode of operation of a fuel cell power plant **18** from G/C to G/I, and vice versa, as will be described in greater detail. When used in G/C mode, the variable controlled by the **PCS** is power delivered (both real and reactive). When used in the G/I mode, the variables controlled are output voltage and frequency, and, if multiple power plants 18 are involved, phase. The output voltage of a three-phase system is, of course, controlled to be at a phase angle of 120^0 between each phase. The outputs of the several fuel cell power plants **18** are collectively joined by bus **15**, which is connected through a delta-to-wye transformer **27** and bus **15'** to the switching gear **12**. The transformer **27** provides a separately derived neutral/ground system for the load

14, and also provides isolation between the fuel cell **PCS** and the load **14** and/or the utility grid bus **10**.

A site supervisory control (SSC) **29** provides the operator interface for the system **8** and may be responsible for control of the system at a high level. The SSC **29** allows the operator to issue high level commands such as "start", "stop", and the like. The SSC **29** may include one or more programmable logic controllers, data processors, computers, sensors, etc. to effect the control of the various components and functions of the system **8**. An operator console **32** provides a display and input capability for the SSC **29**. The SSC **29** may provide limited control of switching gear **12**, as through a link **52**, although principal control of that switching gear occurs automatically by the static switch **19**.

There is also provided a site management control (SMC) **31** for providing direct control of the **PCS**'s of the fuel cells **18**, in response to signals from the static switch module **17**, as well as the grid voltage reference signal **10'** described below. The SMC **31** also may be composed of computers and associated sensors and control circuitry. The SMC **31** may be viewed and considered as an included portion of the SMS **11**. Control bus **33** exchanges control signals between the SMC **31** and the **PCS**'s of fuel cells **18**. Control signals may also be exchanged between the SSC **29** and the fuel cells **18** via control bus **35**, here shown in broken line. Control signals are exchanged between the SMC **31** and the static switch module **17** via control bus **40**. A voltage, or potential, transformer **37** senses the 480 V_{ac} grid voltage and communicates the stepped-down 120 V_{ac} value, via bus **10'**, to the SMC **31** and the static switch module **17** for the purpose of providing control signals indicative of the grid's voltage, phase

and frequency. The depicted location and quantity of transformer(s) **37** is mainly symbolic, and it should be understood that such transformer(s) may, alternatively, be incorporated as part of the control circuit or module for which the control signal is provided. A current transformer **41** senses the load current in a power bus path **39** connected to the loads **14**, and communicates the value to the static switch module **17** via bus **43**. Similarly, current transformer **42** senses grid current and communicates the value to the static switch module **17** via bus **44**, and voltage transformer **46** senses load voltage and transmits it to the static switch module **17** via bus **48**.

Returning to further consideration of the switching gear **12**, with reference additionally to Fig. **4**, the power bus **15'** from the fuel cells **18** is connected through breaker **21** to one pole of the static switch **19**. The power bus path **39** extends from that pole of the static switch **19** through a normally-closed isolation switch **25** to the loads **14**. The utility grid power bus **10** is extended to the other pole of the static switch **19** through breaker **23**. The breaker switches **21** and **23** are intended to be closed during normal operation, such that power from the fuel cells **18** and/or the utility grid **10** may be supplied to the loads **14**, assuming the static switch **19** is closed. Similarly, assuming the power delivered by the fuel cells **18** to the critical loads **14** is less than the cells' entire power output, the excess power from the fuel cells **18** may be delivered through the static switch 19 to the utility grid, or at least to customer non-critical loads (not shown) located on the grid side of static switch **19**. In fact, this is the preferred economic mode of operation in that it maximizes the use of the fuel cells **18** and minimizes the need for and cost of, power from grid **10**.

A bypass breaker switch **21A**, connected from power bus **15'** to the power bus path **39** between the loads **14** and the isolation switch **25** and being normally open, serves, when closed, to bypass breaker switch **21** for purposes of maintenance or isolation. Similarly, a bypass breaker switch **23A**, connected from the utility grid bus **10** to the power bus path **39** between the loads **14** and the isolation switch **25** and being normally open, serves, when closed, to bypass breaker switch **23** and static switch **19** to supply grid power to loads **14**, in the event the static switch fails or during maintenance or during a load fault sufficiently large to exceed the rating of the static switch. Breakers **21**, **23**, and **23A** are electrically operated and are automatically controlled by the static switch **19** to perform transfers in 5 or 6 cycles, e.g., about 80-100 ms. The breaker switch **21A** and isolation switch **25** are manual. The switches **21**,**23**, and **23A** can also be manually controlled by the SSC **29**. Each of the switches **21**, **21A**, **23**, **23a**, and **25** is rated 2000 amperes, and the circuit breakers have a fault interrupting rating of 65 kaic. The general communication link **52**, shown in broken line between the switching gear **12** and the SSC **29**, serves to convey appropriate status and manual control signals therebetween for the static switch **19** and the several breakers **21**, **23**, **23A**, etc. Control logic **49** associated with static switch module **17**, and particularly a switchgear control logic portion **49B** thereof, serves to control the several breakers and switches **21**, **21A**, **23**, and **23A**, as represented by the broken line control paths **21'**, **21A'**, **23'**, and **23A'** extending thereto. The control logic **49** is generally comprised of a high-speed logic portion **49A** for rapidly controlling the static switch **19**, and a relatively slower-speed portion **49B** for controlling the remainder of switchgear **12**.

Referring still further to Fig. **4**, the static switch module **17** is depicted in greater detail. Although the static switch **19** is in fact three pairs of SCRs (thyristors), each pair being connected in parallel-opposed relation for conduction in either direction if the respective control gates **19G** are enabled, only one of those SCRs is depicted in this view. The three pairs of SCRs are respectively for each of the 3 phases of power supply. Normally, the control gates **19G** are connected in common and controlled in unison. Power on utility grid bus **10** and/or power on the fuel cell bus **15/15'** may flow through the SCR's **19** when the control gates **19G** are enabled, thereby allowing either source to power the loads **14**.

The normal mode is G/C in which the utility grid **10** and the fuel cells **18** are connected. The module **17** includes circuitry **45** for sensing when the supply of power from the utility grid bus **10** is out of limits. Typically, these limits include a voltage and a current range relative to the standard or nominal values, and the sensing circuitry **45** provides a signal on lead **47** to control logic **49**, and static switch control logic **49A** thereof specifically, to indicate when the grid is outside those limits. The sensing or detection circuitry **45** is fast acting, providing a response in about 2ms. Although not depicted, a separate fast acting frequency detector may monitor the grid frequency and provide an "in" or "out" "of limits" signal to the static switch control logic **49A**. "Out of limit" grid signal values include, for example,: a) instantaneous grid voltage magnitudes, on any phase, outside the range of 480v +8% to - 15%; b) instantaneous over-current, on any phase, greater than 2,000 amperes; c) frequency deviations from nominal 60Hz value for more than 0.5 sec.; as well as others. The control logic **49A** acts in response to the

grid going out of limits, to provide a signal to the SCR gates **19G** to disable them. The SCR's **19** will rapidly commutate off, thereby disconnecting the utility grid bus **10** from both the loads **14** and the fuel cells **18**. A current sensor **42'** senses the current through the SCRs and provides an indication to the control logic **49A** of the occurrence of zero current through the SCRs. This information is used by the logic **49A** to make the SCR commutation faster. This entire action typically occurs in about ¼ cycle (4 ms), thus facilitating a seamless transfer of power sources from the grid **10** and the fuel cells **18**, to the fuel cells 18 alone, with the fuel cells reconfiguring as rapidly, as will be explained. This is significantly faster than the 8 ms or more required to commutate an SCR using conventional line commutation.

The control logic **49B** also uses the voltage and current sensors **37**, **41**, **42**, and **46** to operate the switching gear devices **21**, **23**, and **23A** under various grid, load, and fuel cell out of limit or fault, conditions. For example, if a load over-current condition exists such that the current rating of the static switch **19** may be exceeded, switch **23A** is closed to conduct the fault current to the load **14**, by-passing the static switch. As a further example, a fuel cell fault can be indirectly detected by observing a low load voltage and perhaps a high grid current but no load over-current. In such event, switch **21** is opened to isolate the fuel cell fault from the load **14**. The control logic **49A** also provides an M1 mode signal on lead **401** and an M2 mode signal on lead **402**. For manual control from the SSC **29**, a G/I status signal is provided by control logic **49** on lead **403**, and a SW19 Enable signal is received on lead **404**. The signals **401** and **402** are part of the control signal bus **40**, and the signals on leads **403** and **404** may be conveyed via communications link **52**. When the sensing

circuitry **45** senses the grid to be out of limits, it causes the M2 mode signal on lead **402** to transition from an "Off" to an "On" state to signal a need for, and to initiate, a mode change. Similarly, but slightly delayed, when the static switch **19** has actually opened in response to the sensed out of limits condition of the grid, the M1 mode signal on lead **401** transitions from an "Off" to an "On" state to signal nominal completion of the mode change. The reverse occurs when the sensing circuitry determines that the grid power supply has been returned to within the acceptable limits, with the M2 signal again leading the M1 signal.

Referring to Fig. **5**, a relevant portion of the SMC **31** and its control of the fuel cell **18 PCS**s is depicted in greater detail, though it will be understood that the SMC provides additional control functions such as load sharing and the like, not shown. As mentioned above, the potential transformer **37**, here depicted in the alternative as a separate transformer **37'**, is incorporated as part of the SMC **31**. The M1 and M2 signals from the static switch module **17** are inputted to an interface circuit **51**, which conditions each of those signals to provide respective discrete signals D1 and D2 on leads **401'** and **402'** connected to the **PCS** portions of each of the several fuel cell power plants **18** for controlling gating and sequencing of the inverters (not shown) therein during mode changes.

Synchronization of the fuel cell power plants **18** in either the G/C or the G/I mode is effected by a "sync" signal appearing on lead **53**. The sync signal is provided through a phase-lock loop **55** receiving alternative inputs, through switch **57**, from either a zero-crossing detector **59** connected to the stepped-down utility grid bus **10'** or an internal frequency source, such as crystal **61**. A "loss of grid" detector **63**, similar to circuit **45**,

is connected to the stepped-down utility grid bus **10′**, and provides a control signal which actuates 3-pole switch **57** as a function of whether or not the grid power is within limits. The interface circuit **51** also is responsive to the M1 and M2 mode signals to provide a signal extended to switch **57** to toggle that switch as a function of the respective mode. It will be understood that detector **63** might be omitted and the output of detector circuit **45** from module **17** used in its stead to control the M1 and M2 mode signals applied to interface circuit **51**, which in turn controls the switch **57**. The switch is depicted in the normal G/C mode in which the synchronization signal provided to the **PCS** of the fuel cells **18** is that of the utility, such that the frequency and phase of the outputs from the fuel cell inverters are controlled to become and be, the same as it.

When the system **8** operates in the G/I mode, the frequency and phasing of the outputs of fuel cells **18** is determined by the crystal **61**. When the utility grid power source returns to within limits and the system **8** is to be returned to the G/C mode, the phase and frequency sources are similarly returned. The phase lock loop **55** slews the sync signal in its transition from one mode to the other to avoid steps or discontinuities.

The solid state inverters of the **PCS**s of the respective fuel cell power plants **18**, and the high speed solid state gates (not shown) which control them, are capable of responding in the ¼ cycle (4 ms) needed for the seamless transfer of power sources. Thus, these inverters, through control of their gates by the mode control signals D1 and D2, are able to effect mode changes of the fuel cells **18** rapidly enough to accomplish the seamless transfers. This enables the fuel cell power plants 18 to operate substantially continuously in a power generating mode, either G/C or G/I, with but a

momentary (less than 4 ms) interruption as they are reconfigured for operating in the opposite mode. The power conditioning systems (**PCS**s), and particularly their inverters and associated gating logic and control, for each fuel cell power plant **18** are of a type manufactured by Magne Tek Inc. of New Berlin, Wisconsin.

Reference to the Table depicted in Fig.**6**, in combination with the description of the power system **8** provided above and hereinafter, will complete an understanding of the invention. During normal G/C operation, both mode signals M1 and M2, and thus also D1 and D2, are "Off", the static switch **19** is "On" (conducting/closed), the inverter gates in the **PCS**s are enabled, and the sync for the system **8**, and particularly the fuel cell **PCS**s, is provided by the utility grid bus **10**. However, when the grid voltage, current or frequency parameters depart from (go outside of) the predetermined limits, the system mode of operation instantly begins the transfer to the G/I mode.

Specifically, M2 rapidly transitions to "On", while M1 remains "Off" for the brief interval required for switch **19** to transition from "On" to "Off". The discrete signals D1 and D2 have the same states as M1 and M2, respectively. The transition of signal M2 (and thus D2) to the "On" state serves to briefly turn "Off" the inverter gates in the **PCS**s such that, for a brief interval less than 4 ms, the **PCS**s of the fuel cells **18** do not provide an electrical power output while they are being reconfigured to the G/I mode of operation. During this interval, the **PCS** output regulators are being reconfigured, such that in the G/C mode they regulate power (real) and VARs and in the G/C mode they regulate voltage and frequency. The sync is also being reconfigured during this interval. This interruption is sufficiently brief and the switch **19** sufficiently fast,

that there is little or no chance for an overload on grid **10** to adversely impact the remainder of power system **8**.

After this brief interval of 4 ms, or less, the system **8** is reconfigured and operating in the G/I mode. The mode signals M1 and M2 (and thus also, D1 and D2) are both "On", the switch **19** is "Off" (open) such that the system is disconnected from the utility grid bus **8**, and the inverter gates in the **PCS**s are again on to provide power to the load(s) **14** from the fuel cells **18**. At this time, the output from the **PCS**s is being "clocked", or synchronized, by the crystal **61**. In the G/I mode, the fuel cell power plants **18** supply, or continue to supply, power to the loads **14** at regulated voltage and frequency without involvement of the utility grid, at least to the maximum capacity of the collective fuel cells.

At such time as the utility grid bus **10** comes back within acceptable limits as determined by sensor **45**, the control logic **49** of the static switch module **17** reverses the prior mode change sequence and begins the transition from the G/I mode back to the G/C mode. Mode signal M2 first goes "Off" while M1 briefly remains "On", the switch **19** quickly transitions from "Off" to "On" such that the utility grid bus **10** is once again connected to the loads **14** together with the fuel cells **18**, the **PCS** inverter gates are again briefly "Off" during reconfiguring, and the **PCS** synchronization is changing from reliance on crystal **61** to that of the utility grid supply. The internal **PCS** output regulation changes from voltage and frequency to power and VARs. Following the brief interval (less than 4 ms) for reconfiguring, the system **8** has been returned to the G/C state, or mode.

Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes,

omissions and additions may be made without departing from the spirit and scope of the invention. For example, the static switch module **17**, and particularly switch **19** therein, is/are depicted as being separate from and external to, the fuel cells **18** and their respective **PCS**'s, thus providing the economy of singular control elements responsible for controlling multiple fuel cells. However, it will be appreciated that these controls could be integral with or internal to the respective fuel cells, particularly if there is but a single fuel cell power plant. Moreover, although the static switch **19** is described in the context of pairs of SCRs, it will be appreciated that other static switching devices capable of similar switching speeds and current ratings may also be used. It will also be understood that a greater or lesser number of fuel cell power plants may be employed, and both the voltage and the current ratings associated with the elements discussed herein may be greater or less than described. Similarly, the control circuits described herein as being in the static switch module **17** could reside in the SMC **31**.